Trace Metals Concentrations in Stormwater Runoff from the Evergreen Point Floating Bridge in the Seattle, Washington Area

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Abstract
Stormwater runoff is a leading cause of trace metals pollution of water bodies in the Seattle area, resulting in a degradation of aquatic habitats. Runoff from bridges is discharged directly into their respective underlying water body without any prior pretreatment. Samples of bridge runoff were collected using clean techniques (EPA Method 1669) at the Evergreen Point floating bridge in the Seattle area. Concentrations of trace metals were measured from samples collected at both low- and high-traffic volume times at the Hwy 520 floating bridge. Results showed elevated concentrations of metals, especially copper and zinc, when compared to the water body accepting the discharge. During high-volume traffic times, these concentrations were up to three times higher than at the low-traffic-volume times. Areas of further investigation would be to collect composite samples according to Washington state stormwater regulations.

Introduction
The Evergreen Point floating bridge is a major corridor connecting Seattle to the eastside communities of Bellevue, Redmond and Kirkland. The bridge is the largest floating pontoon bridge in the world. When the bridge was first opened to motor vehicles in 1963 there was little concern as to the effects of stormwater runoff to the underlying receiving waters. As population dramatically increased over the next 40 years, bridge congestion significantly increased to the point where current traffic patterns exceed the bridge's original design capacity. This increase in bridge traffic has undoubtedly led to pollutant loading from motor vehicles, such as brake dust, exhaust and tires. Baring an extreme storm, experts indicate that the bridge has a remaining life span of 20 to 25 years before the pontoons need replacing. The Washington State Department of Transportation (WSDOT) is currently in the process of drafting plans for possible replacements.

In this study, samples were collected from four different stormwater drains on the east and west sides of the bridge. One of the drains at Foster Island in the Arboretum was collected on three different dates, each with varying amounts of traffic. The stormwater drain on Foster Island was chosen due to the fact that it can be easily accessed by foot. Other drains were accessed by canoe. Grab samples from the Lake Washington receiving water were also collected. The purpose of this study was to determine the trace metal concentrations in the stormwater runoff and to observe the effects that varying traffic volumes have on the trace metals load.

Materials and Methods
Samples were collected using clean techniques as described in EPA Method 1669 "Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria". All sample bottles were Teflon (for mercury analysis) or high-density polyethylene (for analysis of other trace metals). These bottles were previously acid-cleaned according to the established protocols of Frontier Geosciences. All sample processing and analysis occurred at Frontier Geosciences in clean areas known to be free of trace metals. Samples designated for the analysis of dissolved trace metals were filtered using disposable 0.45μm-Nalgene filters. The samples for total and dissolved mercury analysis were preserved and oxidized to 1% (v/v) with 0.2 N BrCl and digested overnight at room temperature prior to analysis by cold vapor atomic fluorescence spectroscopy. The samples for trace metals analysis were preserved to 1% (v/v) with concentrated HNO_3 prior to analysis by inductively coupled plasma-mass spectroscopy.

A summary of the sampling events can be found in Table 1. It should be noted that the Medina drain, which is approximately 60 feet high, posed a problem for collection. A sample was collected by placing a cooler under the discharge area and rinsing the cooler three times with the runoff. After rinsing, the cooler was allowed to fill with the runoff, which was then poured into a sample bottle.

Table 1. Summary of sampling events.

	First Event	Second Event	Third Event
Date	1/21/03	1/21/03	3/8/03
Time	9:10 - 10:45 AM	10:15 AM	2:30 - 3:30 AM
Sampling Sites and Traffic Direction	Foster Island (westbound) Mid Span Drains (eastbound) Medina (westbound)	Foster Island (westbound)	Foster Island (westbound)
Traffic Flow	Low	High	Medium
Notes	Mid Span accessed by canoe Medina Drain not ideal	Drain Pipe Only	Flow Rate Determined Lake Samples Collected

Results and Discussion

All sample results are summarized in Tables 2 – 5. The Foster Island stormwater drain results in Table 1 show that an increase in traffic volume has a strong correlation with trace metals concentrations. Metal concentrations increased at least two-fold between the high- and low-traffic sampling events. Unfortunately, flow rates were only measured at one sampling event. The 410 mL min^{-1} that was recorded at the Foster Island drain is unique to that site. The difference of hydrology throughout the bridge will yield varying flows and this difference can be visually recognized. If there are approximately 350 of these bridge drains, then one can extrapolate that during this sampling event there was approximately 140 L/min stormwater runoff discharged into Lake Washington. The corresponding grab samples near the Foster Island drain (Table 2) yielded detectable trace metal concentrations. It is interesting to note that the grab sample that was collected furthest from the drain (approx. 30 feet) yielded higher concentrations than the grab sample collected near the drain. This could be due to the fact that the second grab was collected approximately 50 feet from another drain. The lake was flowing towards the second sampling point, which may have accumulated suspended sediment and possibly increased trace metals loading.

Results in Table 4 show how the hydrology of the bridge may affect trace metals concentrations in two drains that are separated by approximately 200 feet. Both drains are on the eastbound lanes. Samples were collected from east to west. Results for the samples that were collected in Medina are shown in Table 5. It is important to note, as stated earlier, that the sample from the Medina stormwater drain was not collected under ideal conditions. The King County Department of Natural Resources collected samples at three sites on Lake Washington in September 2000, and the results can be seen in Table 6. These background metals, with the exception of lead and zinc, correlate well to the grab samples collected for this study. More research should be conducted to determine if the background levels of zinc and lead have increased over the past 3 years, and if they will continue to do so.

Table 2: Trace Metals Concentrations Collected at Foster Island Storm Water Drain.

	Foster Island Drain		**Foster Island Drain**	**Foster Island Drain**	
Analyte (µg/L)	**Total**	**Dissolved**	**Total**	**Total**	**Dissolved**
Aluminum	488	31.0	2450	1880	44.9
Chromium	3.10	1.14	8.03	5.20	1.05
Nickel	2.57	0.87	7.71	6.74	2.72
Copper	34.2	9.32	58.5	53.8	28.6
Zinc	52.7	21.2	158	144	48.7
Arsenic	0.94	0.68	2.01	1.15	0.55
Selenium	< 0.30	< 0.30	< 0.30	< 0.30	< 0.30
Silver	< 0.015	< 0.015	< 0.015	0.018	< 0.015
Cadmium	0.170	0.078	0.514	0.323	0.160
Lead	6.07	0.179	15.1	12.1	0.345
Mercury (ng/L)	5.23	-	11.7	8.51	2.92
Hardness (mg/L)	21.4	20.8	49.4	73.0	66.0
TSS (mg/L)	-	-	-	47.0	-
Average Flow Rate	-		-	410 mls min^{-1}	
Date Collected	1/12/03		1/21/03	3/8/03	
Traffic Volume	Low		High	Medium	

Table 3. Trace metals concentrations from Lake Washington.

	Foster Island Grab 1		Foster Island Grab 2	
Analyte (µg/L)	**Total**	**Dissolved**	**Total**	**Dissolved**
Aluminum	22.0	0.80	90.8	2.05
Chromium	0.17	0.12	0.31	0.13
Nickel	0.33	0.26	0.48	0.29
Copper	1.23	0.95	1.81	1.07
Zinc	1.98	1.13	4.36	1.84
Arsenic	0.35	0.30	0.43	0.35
Selenium	< 0.30	< 0.30	< 0.30	< 0.30
Silver	< 0.015	< 0.015	< 0.015	< 0.015
Cadmium	< 0.008	< 0.008	< 0.008	< 0.008
Lead	0.308	0.017	1.15	0.047
Mercury (ng/L)	0.66	0.33	0.75	0.23
Hardness (mg/L)	36.5	34.9	36.7	35.5
TSS (mg/L)	3.3	-	1.7	-
Date Collected	3/8/03		3/8/03	
Traffic Volume	Medium		Medium	

Table 4. Trace Metals Concentrations from Mid Span Storm Water.

Drains and Lake Washington Receiving Water			
Analyte (µg/L)	**Mid Span Drain #1 Total**	**Lake Washington Grab Total**	**Mid Span Drain #2 Total**
Aluminum	546	19.4	1840
Chromium	4.56	0.20	8.27
Nickel	3.82	0.37	6.72
Copper	41.7	1.75	51.3
Zinc	80.8	1.76	117
Arsenic	0.53	0.66	0.99
Selenium	< 0.30	< 0.30	< 0.30
Silver	< 0.015	< 0.015	0.016
Cadmium	0.321	< 0.008	0.368
Lead	9.43	0.184	17.8
Mercury (ng/L)	9.58	1.26	9.15
Hardness (mg/L)	12.4	34.6	16.5
Date Collected	1/12/03	1/12/03	1/12/03
Traffic Volume	Low	Low	Low

Table 5. Trace Metals Concentrations from Medina.

Drain and Lake Washington Receiving Water		
Analyte (µg/L)	**Medina Lake Grab Total**	**Medina Drain Total**
Aluminum	135	1100
Chromium	0.33	4.58
Nickel	0.84	4.65
Copper	2.05	40.9
Zinc	4.00	102
Arsenic	0.77	0.61
Selenium	< 0.30	< 0.30
Silver	< 0.015	< 0.015
Cadmium	< 0.008	0.305
Lead	0.363	8.40
Mercury (ng/L)	1.88	7.98
Hardness (mg/L)	95.3	13.4
Date Collected	1/12/03	1/12/03
Traffic Volume	Low	Low

Table 6. Background Metals in Lake Washington. *(Provided by King County Dept. of Natural Resources)*

Background Metals in Lake Washington		
Analyte (µg/L)	**Total**	**Dissolved**
Aluminum	-	-
Chromium	0.17	0.13
Nickel	0.50	0.47
Copper	1.01	0.89
Zinc	0.76	0.70
Arsenic	-	-
Selenium	-	-
Silver	-	-
Cadmium	0.005	0.005
Lead	0.066	0.013
Mercury (ng/L)	0.43	0.261
Hardness (mg/L)	38.0	-

Conclusion

The data presented clearly indicate that there are trace metals in the stormwater runoff from the Evergreen Point Floating Bridge. The collection of samples at the Foster Island drain shows that increasing traffic volumes will increase trace metal pollutant loading in stormwater. The bridge is also used by commercial shippers and is susceptible to hazardous materials being discharged into Lake Washington in the event of an accident. Future sampling events should include the collection of one-hour composite samples (in accordance with Washington State stormwater regulations) and determination of flow rates at all sites. This will help with data interpretation and the application of that data into current and future water quality standards.

Acknowledgements

- Lucas Hawkins and Paul Fredrickson for sampling assistance
- Frontier Geosciences Inc.
- Puget Soundkeepers Alliance – Sue Joerger

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